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Refrigeration Plant Operated in Parallel with Central Station

Electrical Engineering

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REFRIGERATION PLANT
OPERATED IN PARALLEL WITH CENTRAL STATION

BY

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THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED Refrigeration Plant Operated in Parallel with Central Station

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

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INTRODUCTION

Due to the great competition in all lines of industry each successful shop or factory must be run at the highest efficiency to be able to compete in the open field.

An electric light plant is not run at its highest efficiency if its machinery must stand idle the greater part of the day. It has been a problem for central station managers to try and fill up the hollows in their load curves. The combination ice and electric plant has been installed with this end in view and from all indications the ice plant has been found to be a very suitable day load.

The possibility of a uniform 24 hour load is the central station manager's most important consideration. In the ordinary lighting plant the large engines and thousands of dollars worth of expensive machinery are idle during the day and are taxed to their utmost only in the evening when the peak or heavy lighting load is on. During the day, of course, a small generator is all that is necessary to carry the load, but the boiler must be kept in operation regardless of the small load.

The energetic efforts of the solicitors in selling flat irons and single phase motors and the swiftly developing field of the factories operated by motors during the day hours have greatly increased the revenue of the 24 hour station, so that now many companies recognize the practicability of offering reduced rates for power during their light load, or even of expending considerable capital in order to encourage the use of electric power during the day time.

The power used in the manufacture of ice has always been considered a desirable load for the station, because the power consumed is generally steady for the entire 24 hours and comes at the season when the lighting load is light, namely, during the summer.

The recently developed process in which the complete process of making ice is carried through in less than 24 hours places the ice business in an entirely new light to the cen-

tral station managers. In other words a station may supply power to an ice-making plant without any disturbance or addition to the peak load, since the ice plant apparatus may be completely shut down and the ice harvested during the heavy load period. In supplying power to an artificial ice-making plant, the station can safely figure on a load of two kilowatts for every ton of capacity of the ice plant, so that a twenty ton plant would consume forty kilowatts for twenty hours, assuming a complete freeze to take twenty hours, or 800 kilowatt hours every day. The added cost to the station to produce this 800 kilowatt hours would only be an additional two tons of coal per day. All friction and boiler losses would not enter into this item, since the engines would be operating even though this load was not on. The cost of oil, wages and repair remaining the same, so that the manager can easily afford to make a concession from the usual rate, since the cost per kilowatt hour for this day load power, will be about one-half of a cent to the station manager, assuming the cost of coal to be $2.00 per ton. On the other hand, the returns to the consumer from his ice sales should bring a suitable profit, since twenty tons of ice can be turned out every day with an outlay of only forty kilowatt hours per ton. With ice valued at $4.00 per ton at the plant, the ice manufacturer could well afford to pay from two to four cents per kilowatt hour for his power, which would be $.03 x 40 = $1.20 per ton of ice.

The profits of the central station manager would

be 800 kilowatt hours at \$.03 per kilowatt hour minus the cost of coal. If coal were \$2 per ton, two tons being used to produce this power, his net earnings would be (800 x .03) - (2 x 2) = \$20 per day from his ice plant consumer. A still better proposition would, of course, be the installation and operation of the ice plant by the central station management. With a short transmission, attendance always at hand, an absolute control of the load so connected. The ice plant could be run only at such hours as were advantageous to the station and at a very little cost. The station engineer can readily adapt himself to the care of the brine pumps and other machines of the ice plant.

The installing of the proper machinery has a great deal to do with the economy of the plant. Although the machines as units may be of the best, their relative value when working in unison will not be up to their individual ratings.

If the owner of a small electric light and power plant, wishes to put in an ice factory he goes to the manufacturer of ice-making machinery, and the manufacturer hands down one of his standard steam-driven plants such as would be advisable to install in an independent ice factory. As a result some of the important economies of operating an ice plant in connection with an electric plant may be deliberately thrown away by such an installation.

If the ice plant is of the compression type, which is the most commonly used, ~~nearly entirely~~ by small installa-

tions, it requires essentially for its operation two things which the electric plant can supply; namely, exhaust steam for condensation to make the necessary distilled water for ice manufacture, and the power for driving the compressor. Now, the ice machine manufacturer when asked to install such a plant, is prone to ignore the existence of a large amount of exhaust steam, from the electric plant. He also ignores the economy with which power can be produced by the electric plant.

The question now comes up as to whether the ice plant should be driven by steam or by a motor. Which is the most economical? If the ice plant be motor driven, the amount of exhaust steam which would be furnished by the electric plant could hardly fail to be sufficient for furnishing the distilled water for ice making. It is usually figured by ice making manufacturers that in plants of from ten to twenty ton capacity, such as would probably be installed by a small central station, that the exhaust steam from the engines required to operate the compressors and circulating pumps will be just sufficient to supply distilled water for ice making, provided a fairly uneconomical type of engine be used. It is, therefore, apparent that with the electric plant already carrying some day load, and with the addition of motors for driving the ice machines, there will be sufficient exhaust steam for ice manufacture.

Now, the engine driving the electric generators may not have a much better inherent fuel economy than the

engine which would drive the ice machine. The economy of the motor drive in such a case is brought about by the fact that there are certain fixed losses in connection with the operation of the ice making engine and there are also certain fixed losses with the operation of the electric plant engines.

The operation of both plants from one engine cuts off one set of these fixed losses. The addition of an ice plant motor will simply give to the electric plant a load which its engines can carry with fair economy, where otherwise they would be running underload with poor economy twenty hours of the day.

A plant of this type, electrically driven, would require a motor say of the induction type to drive the compressor, the size of this motor would depend entirely upon the output of the plant, and a small motor to keep the brine in circulation.

The cost of operation of these two motors, I dare say, would not be noticable on the central station and the ice would be manufactured for nearly nothing as far as power and distilled water are concerned and these constitute large items.

COST OF OPERATING A FIFTEEN TON

INDEPENDENT ICE PLANT

In the following discussion I will try to bring out the cost of the manufacture of one ton of ice. The plant is to use the absorption system and to have a capacity of fifteen tons per day.

What does it cost to manufacture a ton of ice? By referring to catalogues sent out by manufacturers of different ice making machinery, I find that they have compiled tables showing the cost, and what it is made up of, for factories of different sizes. But as could be expected, they are somewhat misleading. The manufacturers estimate for a fifteen ton plant averages up to $1.12 per ton.

This is made up of the following items per day.

2 engineers	$3.75
2 tankmen	2.00
6,700 lbs. of coal at $3.00 per ton	10.05
Oil, lights, waste, sundries	1.00
Total	$16.80

Making a total of $16.80 for the manufacture of fifteen tons of ice.

These items are a little low for the present day rate of wages and a better list would be somewhat higher.

Referring to the first item, that of engineers' salary, there is only an allowance of $3.75, whereas two engineers capable of handling this class of machinery in first class style would cost at least $2.25 apiece, or $4.50. The quality and even the quantity of ice turned out each day rest nearly entirely with the engineers and the best investment that could be made would be to hire competent engineers. It is impossible to hire engineers or tankmen by the hour or day unless the work is reasonably steady the year round which is hardly possible for an independent plant to grant. In the above table no allowance has been made for the fireman and this work would have to be done by the engineers.

The second item of expense for tankmen is rather low, for these men must be clean and we could hardly expect a man to give ten hours of his time each day for $1. So this item should be at least $3 for the two tankmen.

As to the item of fuel, it seems as if the estimate is rather high, allowing 6,700 lbs. of coal per day, as it was impossible for me to obtain any figure with which to make a comparison, for nearly all small plants are run in such a haphazard way, no data or cost which amount to anything can be obtained.

But coal can be bought delivered by contract for $2 per ton in this section of the country, which would bring the coal item down to $6.75.

As to the last mentioned item of expense, it should be increased to $1.25 per day so as to be sure and include

all small items which would naturally be figured very low by the ice machine manufacturers, and this brings us to an item which has been left out in any estimate which I have ever seen, namely, a charge for depreciation, for this item is sure to demand attention sooner or later and a wise manager will set aside a proper amount to take care of this item each year. What the proper amount per ton of ice should be will depend upon the total annual output of the factory and what the total depreciation charges amount to. The cost of a fifteen ton plant, including real estate, plant and boilers, is about $1000 per ton of ice for a total of $15,000.

Estimating the life of an ice plant as fifteen years this means that a sum of about one thousand dollars per annum must be set aside to replace equipment. Under ordinarily favorable conditions the ice season does not last over six months, which means that a fifteen ton plant would only turn out 2,700 tons of ice running full capacity. But assuming that 300 tons could be manufactured during the other six months which would make a total of 3000 tons for the year, which means that a sum of 33-1/3 cents must be set aside for depreciation charges for each ton of ice turned out.

If the changes in this estimate of $1.12 per ton are to be accepted as being more nearly correct for a small ice factory in actual operation, and according to these figures they ought to be, the actual cost per day for an inde-

pendently operated ice factory having a capacity of fifteen tons would be as follows:

2 engineers	$4.50
2 tankmen	3.00
6,700 lbs. of coal	6.75
Oil, light, waste, ammonia.etc.	1.25
Depreciation charges based on 3,000 tons annual output	5.00
Total	$20.50

This makes a total of $20.50 for the manufacture of fifteen tons of ice or an average of approximately $1.37 per ton.

The question which now suggests itself is: How does this price compare with the cost of harvesting natural ice? The best that I can do is to quote the price given me by a natural-ice dealer; he claims $1.10 per ton to put it in the ice house. To this he added the shrinkage which he estimated at a little under fifty percent for all ice put in storage so that it cost him $2.00 per ton. The above are the figures of one dealer and not an average, so can not be very reliable.

There is no doubt but that natural ice can be put up for less than the above amount in some localities, especially where the lake or pond from which the ice is harvested is owned by the parties putting up the ice, and where the ice does not have to be hauled, but run into ice house direct from the lake or pond. Another detriment to natural ice is that it costs fully fifty cents per ton more to deliver than

manufactured ice. This is due to the greater distance in hauling, difficulty in getting it from the ice house and trouble in cleaning. I, therefore, believe that mechanical made ice can be placed in the consumer's box in competition with natural ice and at a greater percent profit than could be made by natural ice people. This is assuming that the ice season lasts at least six months of the year.

Now, if an independently operated ice plant can operate in competition with natural ice and be able to show good returns for the investment, could not the combining of an artificial ice factory with an electric light and power plant be made to show still better returns?

A few suggestions at this time of some of the advantages and savings that might be made by the combination will be of interest.

1. Cost of a complete set of boilers, including boiler house.
2. Cost of two engineers.
3. Saving of coal bill due to boiler losses which remain the same with the ice factory load on as when only electric plant is operated.
4. Saving of nearly all the item of oil, light, waste sundries.

Looking at it from the other side the only extra cost of operating an ice plant in addition to a central station is a small amount of coal, two tankmen or ice pullers, the depreciation on the ice plant, which when itemized would be

2 tankmen	$3.00
Coal	3.00
Depreciation charges on basis of 3,000 tons annual output	4.00
Total	$10.00

Turning to a different phase of ice manufacturing that is from the combined ice and electric plant, to the ice plant operated by power purchased from a central station, I would hardly say that it is a profitable investment, unless the power is very cheap.

The following description will be of an eighty ton electrically operated ice plant.

The ammonia compressor is operated by a 200 H. P., 2200 volt induction motor by means of a rope drive. The ice is manufactured from spring water and produces the ice free from bubbles, the water in the tanks is agitated by means of compressed air admitted from a perforated pipe placed near the bottom of the tank. The circulation produced by the air bubbles floating upward through the water assists in removing the impurities and air bubbles from the surface of the ice. This process is known as making ice of raw water and has not yet reached a very high efficiency; that is, the ice is not as clear as that made of condensed steam.

To handle these large plates of ice which are 16 x 10 x 1 feet and weigh 9400 pounds, two eyebolts are frozen into each cake of ice. A seven ton crane is used to

draw these plates, the cranes operated by two induction motors of three and five horse power capacity, respectively, and of the slip ring type, as the motors are required to start under load.

After the plate is drawn it is placed on a large table, the bolts are removed by passing a heavy current through the rods. A current of 250 amperes will loosen the bolts in about a minute.

The table is operated by a two horse power motor wired for reverse operation as well as direct to allow a range of motion of the table through 180 degrees, this is simply for convenience of handling the large plate.

For distribution the plate is now cut into smaller pieces by a motor operated saw. This saw is mounted on a revolving stand and traveler so arranged that a cut may be made either sidewise or lengthwise of the cake. Only two men are required to handle the entire output of this plant, from the freezing tanks to the loading **platform.** The average daily output is about seventyeight tons, but in hot weather the plant can be pushed to give an output of one hundred tons per day.